Exhibit F

The Effect of Large-Capacity Magazine Bans on High-Fatality Mass Shootings, 1990–2017

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Objectives. To evaluate the effect of large-capacity magazine (LCM) bans on the frequency and lethality of high-fatality mass shootings in the United States.

Methods. We analyzed state panel data of high-fatality mass shootings from 1990 to 2017. We first assessed the relationship between LCM bans overall, and then federal and state bans separately, on (1) the occurrence of high-fatality mass shootings (logit regression) and (2) the deaths resulting from such incidents (negative binomial analysis). We controlled for 10 independent variables, used state fixed effects with a continuous variable for year, and accounted for clustering.

Results. Between 1990 and 2017, there were 69 high-fatality mass shootings. Attacks involving LCMs resulted in a 62% higher mean average death toll. The incidence of high-fatality mass shootings in non–LCM ban states was more than double the rate in LCM ban states; the annual number of deaths was more than 3 times higher. In multivariate analyses, states without an LCM ban experienced significantly more high-fatality mass shootings and a higher death rate from such incidents.

Conclusions. LCM bans appear to reduce both the incidence of, and number of people killed in, high-fatality mass shootings. (*Am J Public Health.* 2019;109:1754–1761. doi: 10.2105/AJPH.2019.305311)

The recent spate of gun massacres in the United States has re-energized the debate over how to prevent such tragedies.[1] A common response to high-profile acts of gun violence is the promotion of tighter gun legislation, and there is some evidence that laws imposing tighter restrictions on access to firearms have been associated with lower levels of mass shootings.[2] One proposal that has received renewed interest involves restricting the possession of large-capacity magazines (LCMs).[3–5] This raises an important question: what has been the impact of LCM bans on high-fatality mass shootings?

In an attempt to arrest an uptick in mass shooting violence in the early 1990s, Congress in 1994 enacted the federal assault weapons ban, which, among other things, restricted ownership of certain ammunition-feeding devices.[6,7] The law, which contained a sunset provision, was allowed to expire a decade later. Pursuant to that ban (18 USC §921(a) [1994]; repealed), it was illegal to possess LCMs—defined as any ammunition-feeding device holding more than 10 bullets—unless the magazines were manufactured before the enactment of the ban. LCM restrictions are arguably the most important component of assault weapons bans because they also apply to semiautomatic firearms without military-style features.[8,9]

Beginning with New Jersey in 1990, some states implemented their own regulations on LCMs. Today, 9 states and the District of Columbia restrict the possession of LCMs. The bans vary along many dimensions, including maximum bullet capacity of permissible magazines, grandfathering of existing LCMs, and applicable firearms. Moreover, overlaps sometimes exist between assault weapons bans and LCM bans, but not in all states. For example, California instituted a ban on assault weapons in 1989, but LCMs remained unregulated in the state until 1994, when the federal ban went into effect. In 2000, California's own statewide ban on LCMs took effect as a safeguard in the event the federal ban expired, which happened in 2004.[10,11]

LCMs provide a distinct advantage to active shooters intent on murdering numerous people: they increase the number of rounds that can be fired at potential victims before having to pause to reload or switch weapons. Evidence shows that victims struck by multiple rounds are more likely to die, with 2 studies finding that, when compared with the fatality rates of gunshot wound victims who were hit by only a single bullet, the fatality rates of those victims hit by more than 1 bullet were more than 60% higher.[12,13] Being able to strike human targets with more than 1 bullet increases shooters' chances of killing their victims. Analyses of gunshot wound victims at level I trauma centers have suggested that this multiple-impact capability is often attributable to the use of LCMs.[14,15]

In addition, LCMs provide active shooters with extended cover.[16] During an attack, perpetrators are either firing their guns or not firing their guns. While gunmen are firing, it is extremely difficult for those in the line of fire to take successful defensive maneuvers. But if gunmen run out of bullets, there are lulls in the shootings, as the perpetrators are forced to pause their attacks to reload or change weapons. These pauses provide opportunities for people to intervene and disrupt a shooting. Alternatively, they provide individuals in

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harm's way with a chance to flee or hide. Legislative endeavors that restrict access to LCMs are implemented with the express objective of reducing an active shooter's multiple-impact capability and extended cover.[10]

Although mass shootings have received extensive study, there has been little scholarly analysis of LCM bans.[17–24] The studies undertaken that have broached the subject of ammunition capacity have primarily concentrated on the effect of LCM bans on violent crimes other than mass shootings or on the impact of the assault weapons bans on mass shootings.[25–27]

Evidence suggests that firearms equipped with LCMs are involved in a disproportionate share of mass shootings.[10,20,28] Proponents of LCM bans believe that without LCMs, fewer people will be killed in a mass shooting, other things equal. In turn, fewer shootings will cross the threshold required to be classified as what we call a "high-fatality mass shooting" (≥6 victims shot to death). If LCM bans are effective, we should expect to find that high-fatality mass shootings occur at a lower incidence rate when LCM bans are in place, and fewer people are killed in such attacks. But have LCM bans actually saved lives in practice? To our knowledge, the impact of LCM bans has never been systematically assessed. This study fills that void.

METHODS

Mass shootings have been defined in a variety of ways, with some analyses setting the casualty threshold as low as 2 people wounded or killed and others requiring a minimum of 7 gunshot victims.[18,22,29] We focused on high-fatality mass shootings—the deadliest and most disturbing of such incidents—which are defined as intentional crimes of gun violence with 6 or more victims shot to death, not including the perpetrators.[20,30,31] After an exhaustive search, we identified 69 such incidents in the United States between 1990 and 2017. We then discerned whether each high-fatality mass shooting involved a LCM—unless otherwise stated, defined consistent with the 1994 federal ban as a detachable ammunition-feeding device capable of holding more than 10 bullets. (See Table 1 for a list of incidents and for additional details on the search and identification strategy we employed.)

The first state to enact an LCM ban was New Jersey in 1990. Since then, another 8 states and the District of Columbia have enacted LCM bans (Table A, available as a supplement to the online version of this article at http://www.ajph.org).[10] With no LCM bans in effect before 1990, a priori we chose that year to begin our analysis to avoid inflating the impact of the bans. Our data set extends 28 years, from 1990 through 2017. As a secondary analysis, we used a 13-year data set, beginning in 2005, the first full year after the federal assault weapons ban expired.

Our primary outcome measures were the incidence of high-fatality mass shootings and the number of victims killed. We distinguished between high-fatality mass shootings occurring with and without a ban in effect. Because the federal ban was in effect nationwide from September 13, 1994, through September 12, 2004, we coded every state as being under an LCM ban during that 10-year timeframe.

Our interest was in the effect of LCM bans. We ran regression analyses to determine if any relationship between LCM bans and high-fatality mass shootings can be explained by other factors. In our state–year panel multivariate analyses, the outcome variables were (1) whether an LCM-involved high-fatality mass shooting occurred, (2) whether any high-fatality mass shooting occurred, (3) the number of fatalities in an LCM-involved high-fatality mass shooting, and (4) the number of fatalities in any high-fatality mass shooting. Our analyses first combined and then separated federal and state LCM bans.

Consistent with the suggestions and practices of the literature on firearm homicides and mass shootings, our explanatory variables are population density; proportion of population aged 19 to 24 years, aged 25 to 34 years, that is Black, and with a college degree; real per-capita median income; unemployment rate; and per-capita prison population.[2,26,27,32] We also added a variable for percentage of households with a firearm. All regression models controlled for total state population. When the dependent variable reflected occurrences of incidents (ordered choice data), we used logit regression; we ran probit regression as a sensitivity analysis. We had multiple observations for individual states. To control for this, we utilized cluster-robust standard errors to account for the clustering of observations. When the dependent variable reflected deaths (count data), we used negative binomial regression; Gius used a Poisson regression, and we used that approach as a sensitivity analysis.[26] We included state fixed effects. We used a continuous variable for year because the rate of high-fatality mass shootings has increased over time. For purposes of sensitivity analysis, we also replaced the linear yearly trend with a quadratic function. We performed multivariate statistical analyses by using Stata/IC version 15.1 (StataCorp LP, College Station, TX).

Population data came from the US Census Bureau, unemployment data came from the Bureau of Labor Statistics, and imprisonment data came from the Bureau of Justice Statistics. The percentage of households with a firearm was a validated proxy (the percentage of suicides that are firearm suicides) derived from Centers for Disease Control and Prevention National Vital Statistics Data.[33]

RESULTS

Between 1990 and 2017, there were 69 high-fatality mass shootings (≥6 victims shot to death) in the United States. Of these, 44 (64%) involved LCMs, 16 did not (23%), and for 9 (13%) we could not determine whether LCMs were used (Table 1). The mean number of victims killed in the 44 LCM-involved high-fatality mass shootings was 11.8; including the unknowns resulted in that average falling to 11.0 (not shown). The mean number of victims killed in high-fatality mass shootings in which the perpetrator did not use an LCM was 7.3 (Table B, available as a supplement to the online version of this article at http://www.ajph.org); including the unknowns resulted in that average falling to 7.1 (not shown). When we excluded unknown cases, the data indicated that utilizing LCMs in high-fatality mass shootings resulted in a 62% increase in the mean death toll.

Data sets of mass shooting fatalities by their nature involve truncated data, with the mode generally being the baseline number of fatalities required to be included in the data set (6 fatalities in the current study). Our data

TABLE 1—High-Fatality Mass Shootings in the United States, 1990–2017

Incident	Date	City	State	LCM	Deaths, No.	State LCM Ban	Federal Assault Weapons Ban
1	Jun 18, 1990	Jacksonville	FL	Y	9	N	N
2	Jan 26, 1991	Chimayo	NM	N	7	N	N
3	Aug 9, 1991	Waddell	AZ	N	9	N	N
4	Oct 16, 1991	Killeen	TX	Y	23	N	N
5	Nov 7, 1992	Morro Bay and Paso Robles	CA	N	6	N	N
6	Jan 8, 1993	Palatine	IL	N	7	N	N
7	May 16, 1993	Fresno	CA	Y	7	N	N
8	Jul 1, 1993	San Francisco	CA	Y	8	N	N
9	Dec 7, 1993	Garden City	NY	Y	6	N	N
10	Apr 20, 1999	Littleton	CO	Y	13	Y	Y
11	Jul 12, 1999	Atlanta	GA	U	6	Y	Y
12	Jul 29, 1999	Atlanta	GA	Y	9	Y	Y
13	Sep 15, 1999	Fort Worth	TX	Y	7	Y	Y
14	Nov 2, 1999	Honolulu	HI	Y	7	Y	Y
15	Dec 26, 2000	Wakefield	MA	Y	7	Y	Y
16	Dec 28, 2000	Philadelphia	PA	Y	7	Y	Y
17	Aug 26, 2002	Rutledge	AL	N	6	Y	Y
18	Jan 15, 2003	Edinburg	TX	U	6	Y	Y
19	Jul 8, 2003	Meridian	MS	N	6	Y	Y
20	Aug 27, 2003	Chicago	IL	N	6	Y	Y
21	Mar 12, 2004	Fresno	CA	N	9	Y	Y
22	Nov 21, 2004	Birchwood	WI	Y	6	N	N
23	Mar 12, 2005	Brookfield	WI	Y	7	N	N
24	Mar 21, 2005	Red Lake	MN	Y	9	N	N
25	Jan 30, 2006	Goleta	CA	Y	7	Y	N
26	Mar 25, 2006	Seattle	WA	Y	6	N	N
27	Jun 1, 2006	Indianapolis	IN	Y	7	N	N
28	Dec 16, 2006	Kansas City	KS	N	6	N	N
29	Apr 16, 2007	Blacksburg	VA	Y	32	N	N
30	Oct 7, 2007	Crandon	WI	Y	6	N	N
31	Dec 5, 2007	Omaha	NE	Y	8	N	N
32	Dec 24, 2007	Carnation	WA	U	6	N	N
33	Feb 7, 2008	Kirkwood	MO	Y	6	N	N
34	Sep 2, 2008	Alger	WA	U	6	N	N
35	Dec 24, 2008	Covina	CA	Y	8	Y	N
36	Jan 27, 2009	Los Angeles	CA	N	6	Y	N
37	Mar 10, 2009	Kinston, Samson, and Geneva	AL	Y	10	N	N
38	Mar 29, 2009	Carthage	NC	N	8	N	N
39	Apr 3, 2009	Binghamton	NY	Y	13	Y	N
40	Nov 5, 2009	Fort Hood	TX	Y	13	N	N
41	Jan 19, 2010	Appomattox	VA	Y	8	N	N

Continued

TABLE 1—*Continued*

Incident	Date	City	State	LCM	Deaths, No.	State LCM Ban	Federal Assault Weapons Ban
42	Aug 3, 2010	Manchester	CT	Y	8	N	N
43	Jan 8, 2011	Tucson	AZ	Y	6	N	N
44	Jul 7, 2011	Grand Rapids	MI	Y	7	N	N
45	Aug 7, 2011	Copley Township	OH	N	7	N	N
46	Oct 12, 2011	Seal Beach	CA	N	8	Y	N
47	Dec 25, 2011	Grapevine	TX	N	6	N	N
48	Apr 2, 2012	Oakland	CA	N	7	Y	N
49	Jul 20, 2012	Aurora	CO	Y	12	N	N
50	Aug 5, 2012	Oak Creek	WI	Y	6	N	N
51	Sep 27, 2012	Minneapolis	MN	Y	6	N	N
52	Dec 14, 2012	Newtown	CT	Y	27	N	N
53	Jul 26, 2013	Hialeah	FL	Y	6	N	N
54	Sep 16, 2013	Washington	DC	N	12	Y	N
55	Jul 9, 2014	Spring	TX	Y	6	N	N
56	Sep 18, 2014	Bell	FL	U	7	N	N
57	Feb 26, 2015	Tyrone	MO	U	7	N	N
58	May 17, 2015	Waco	TX	Y	9	N	N
59	Jun 17, 2015	Charleston	SC	Y	9	N	N
60	Aug 8, 2015	Houston	TX	U	8	N	N
61	Oct 1, 2015	Roseburg	OR	Y	9	N	N
62	Dec 2, 2015	San Bernardino	CA	Y	14	Y	N
63	Feb 21, 2016	Kalamazoo	MI	Y	6	N	N
64	Apr 22, 2016	Piketon	OH	U	8	N	N
65	Jun 12, 2016	Orlando	FL	Y	49	N	N
66	May 27, 2017	Brookhaven	MS	U	8	N	N
67	Sep 10, 2017	Plano	TX	Y	8	N	N
68	Oct 1, 2017	Las Vegas	NV	Y	58	N	N
69	Nov 5, 2017	Sutherland Springs	TX	Y	25	N	N

Note. LCM = large-capacity magazine; N = no; U = unknown; Y = yes. From September 13, 1994, until and including September 12, 2004, each and every state, including the District of Columbia, was subject to a ban on LCMs pursuant to the federal assault weapons ban. To collect the data in Table 1, we searched the following news media resources for every shooting that resulted in 6 or more fatalities: America's Historical Newspapers, EBSCO, Factiva, Gannett Newsstand, Google News Archive, Lexis-Nexis, Newspaper Archive, Newspaper Source Plus, Newspapers.com, Newswires, ProQuest Historical Newspapers, and ProQuest Newsstand. We also reviewed mass shooting data sets maintained by *Mother Jones*, the *New York Times*, and *USA Today*. In addition to news media sources, we reviewed reports on mass shootings produced by think tank, policy advocacy, and governmental organizations, including the US Federal Bureau of Investigation Supplementary Homicide Reports, the crowdsourced Mass Shooting Tracker, and the open-source databases maintained by the Gun Violence Archive and the Stanford University Geospatial Center. Finally, when it was relevant, we also reviewed court records as well as police, forensic, and autopsy reports. As a general rule, when government sources were available, they were preferred over other sources. Furthermore, when media sources conflicted on the number of casualties or the weaponry involved, the later sources were privileged (as later reporting is often more accurate).

set of high-fatality mass shootings was no exception. As such, the median average number of fatalities for each subset of incidents—those involving and those not involving LCMs—was necessarily lower than the mean average. Nevertheless, like the mean average, the median average was higher when LCMs were employed—a median average of 8 fatalities per incident compared with 7 fatalities per incident for attacks not involving LCMs.

For the 60 incidents in which it was known if an LCM was used, in 44 the perpetrator used an LCM. Of the 44 incidents in which the perpetrators used LCMs, 77% (34/44) were in nonban states. In the 16 incidents in which the perpetrators did not use LCMs, 50% (8/16) were in nonban states (Table B, available as a supplement to the online version of this article at http://www.ajph.org). Stated differently, in nonban states, 81% (34/42) of high-fatality mass shooting perpetrators used LCMs; in LCM-ban states, only 55% (10/18) used LCMs.

The rate of high-fatality mass shootings increased considerably after September 2004 (when the federal assault weapons ban expired). In the 10 years the federal ban was in effect, there were 12 high-fatality mass shootings and 89 deaths (an average of 1.2 incidents and 8.9 deaths per year). Since then, through 2017, there have been 48 high-fatality mass shootings and 527 deaths (an average of 3.6 incidents and 39.6 deaths per year in these 13.3 years).

Of the 69 high-fatality mass shootings from 1990 to 2017, 49 occurred in states without an LCM ban in effect at the time and 20 in states with a ban in effect at the time. The annual incidence rate for high-fatality mass shootings in states without an LCM ban was 11.7 per billion population; the annual incidence rate for high-fatality mass shootings in states with an LCM ban was 5.1 per billion population. In that 28-year period, the rate of high-fatality mass shootings per capita was 2.3 times higher in states without an LCM ban (Table 2).

Non–LCM ban states had not only more incidents but also more deaths per incident (10.9 vs 8.2). The average annual number of high-fatality mass shooting deaths per billion population in the non–LCM ban states was 127.4. In the LCM ban states, it was 41.6 (Table 2).

For the time period beginning with the first full calendar year following the expiration of the federal assault weapons ban (January 1, 2005–December 31, 2017), there were 47 high-fatality mass shootings in the United States. Of these, 39 occurred in states where an LCM ban was not in effect, and 8 occurred in LCM ban locations. The annual incidence rate for high-fatality mass shootings in states without an LCM ban was 13.2 per billion population; for states with an LCM ban, it was 7.4 per billion population (Table 2). During this period, non–LCM ban states had not only more incidents but also more deaths per incident (11.4 vs 9.4). In terms of high-fatality mass shooting deaths per billion population, the annual number of deaths in the non–LCM ban states was 150.6; in the LCM ban states it was 69.2 (Table 2).

When we limited the analysis solely to high-fatality mass shootings that definitely involved LCMs, the differences between ban and nonban states became larger. For example, for the entire period of 1990 to 2017, of the 44 high-fatality mass shootings that involved LCMs, the annual incidence rate for LCM-involved high-fatality mass shootings in nonban states was 8.1 per billion population; in LCM-ban states it was 2.5 per billion population. The annual rate of high-fatality mass shooting deaths in the non–LCM ban states was 102.1 per billion population; in the LCM ban states it was 23.3. In terms of LCM-involved high-fatality mass shootings, we also found comparable wide differences in incidence and fatality rates between ban and nonban states for the post–federal assault weapons ban period (2005–2017; Table 2).

We found largely similar results in the multivariate analyses (1990–2017). States that did not ban LCMs were significantly more likely to experience LCM-involved high-fatality mass shootings as well as more likely to experience any high-fatality mass shootings (regardless of whether an LCM was involved). States that did not ban LCMs also experienced significantly more deaths from high-fatality mass shootings, operationalized as the absolute number of fatalities (Table 3).

When the LCM bans were separated into federal and state bans, both remained significantly related to the incidence of LCM-involved high-fatality mass shooting events and to the number of LCM-involved high-fatality mass shooting deaths. The associations between federal and state bans and

TABLE 2—High-Fatality Mass Shootings (≥ 6 Victims Shot to Death) by Whether LCM Bans Were in Effect: United States, 1990–2017

	Average Annual Population, No. (Millions)	Total Incidents, No.	Annual Incidents per Billion Population, No.	Total Deaths, No.	Annual Deaths per Billion Population, No.	Deaths per Incident, No.
All high-fatality mass shootings, 1990–2017 (28 y)						
Non–LCM ban states	149.7	49	11.7	534	127.4	10.9
LCM ban states	140.7	20	5.1	164	41.6	8.2
All high-fatality mass shootings, 2005–2017 (13 y)						
Non–LCM ban states	227.8	39	13.2	446	150.6	11.4
LCM ban states	83.4	8	7.4	75	69.2	9.4
LCM-involved high-fatality mass shootings, 1990–2017 (28 y)						
Non–LCM ban states	149.7	34	8.1	428	102.1	12.6
LCM ban states	140.7	10	2.5	92	23.3	9.2
LCM-involved high-fatality mass shootings, 2005–2017 (13 y)						
Non–LCM ban states	227.8	28	9.5	369	124.6	13.2
LCM ban states	83.4	4	3.7	42	38.7	10.5
Non-LCM high-fatality mass shootings, 1990–2017 (28 y)						
Non–LCM ban states	149.7	8	1.9	56	13.4	7.0
LCM ban states	140.7	8	2.0	60	15.2	7.5

Note. LCM = large-capacity magazine.

TABLE 3—Multivariate Results of the Relationship Between LCM Bans and High-Fatality Mass Shootings (≥ 6 Victims Shot to Death), 1990–2017 Combined Federal and State Large Capacity Magazine Bans: United States

	LCM-Involved High-Fatality Mass Shootings, b (95% CI)		All High-Fatality Mass Shootings, b (95% CI)	
	Incidents[a]	No. Deaths[b]	Incidents[a]	No. Deaths[b]
All LCM bans (federal and state)	−2.217 (−3.493, −0.940)	−5.912 (−9.261, −2.563)	−1.283 (−2.147, −0.420)	−3.660 (−5.695, −1.624)
Population density	−0.011 (−0.052, 0.031)	0.013 (−0.068, 0.095)	0.001 (−0.003, 0.006)	0.011 (−0.005, 0.026)
% aged 19–24 y	−0.480 (−1.689, 0.730)	−2.496 (−5.893, 0.901)	0.283 (−0.599, 1.164)	−0.585 (−2.666, 1.495)
% aged 25–34 y	−0.801 (−1.512, −0.089)	−2.390 (−4.391, −0.388)	−0.337 (−0.871, 0.197)	−1.114 (−2.463, 0.235)
% Black	−0.227 (−1.062, 0.607)	−0.654 (−2.831, 1.522)	−0.163 (−0.703, 0.377)	−0.261 (−1.391, 0.870)
% with a bachelor's degree or higher	−0.009 (−0.492, 0.474)	−0.469 (−1.590, 0.652)	0.143 (−0.214, 0.501)	0.183 (−0.715, 1.081)
Percentage of households with a firearm (proxy)	−0.047 (−0.195, 0.101)	−0.147 (−0.546, 0.251)	−0.020 (−0.131, 0.091)	−0.084 (−0.368, 0.200)
Median household income	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)
Unemployment rate	−0.072 (−0.293, 0.149)	−0.476 (−1.081, 0.129)	0.041 (−0.135, 0.216)	−0.182 (−0.628, 0.263)
Imprisonment rate (per 100 000 population)	−0.006 (−0.012, 0.001)	−0.007 (−0.017, 0.004)	−0.001 (−0.006, 0.003)	−0.003 (−0.012, 0.007)
Total population	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)
Pseudo R^2	0.31	0.16	0.26	0.11

Note. CI = confidence interval; LCM = large-capacity magazine. There were a total of 1428 observations in state-years (51 jurisdictions—all 50 states plus Washington, DC—over a 28-year period). Mean variance inflation factor = 3.49.
[a]Logit regression.
[b]Negative binomial regression.

the overall incidence of all high-fatality mass shootings as well as the total number of victims in these events remained strongly negative but was only sometimes statistically significant (Table 4).

In terms of sensitivity analyses, using probit instead of logit gave us similar results (not shown). When the outcome variable was the number of high-fatality mass shooting deaths, we obtained largely similar results concerning the association between LCM bans and the outcome variables, regardless of whether we used Poisson or negative binominal regression (not shown). Moreover, replacing the linear yearly trend with a quadratic function did not change the major results of the analyses (not shown). Variance inflation factors for all the independent variables never exceeded 10.0, with the variance inflation factor for LCM ban variables always being less than 2.0, indicating that there were no significant multicollinearity issues (Tables 3 and 4).

DISCUSSION

In the United States, LCMs are disproportionately used in high-fatality mass shootings (incidents in which ≥ 6 victims are shot to death). In at least 64% of the incidents since 1990, perpetrators used LCMs. (For 23%, we determined that they did not involve LCMs, and a determination could not be made for the remaining 13%.) Previous research has shown that LCM firearms are used in a high share of mass murders (typically defined as ≥ 4 homicides) and murders of police.[9]

We could not find reliable estimates of LCM firearms in the US gun stock. However, it is likely much lower than 64%, given that commonly owned firearms such as revolvers, bolt-action rifles, and shotguns are not typically designed to be LCM-capable. During the decade the federal assault weapons ban was in effect, no firearms were legally manufactured with LCMs for sale in the United States. In the postban era, semiautomatic firearms, especially pistols, are often sold with factory-issue LCMs, but firearms that are not semiautomatic are not sold with such magazines.

Why do we find LCMs so prominent among high-fatality mass shootings? We suspect there are 2 main reasons. The first is that perpetrators probably deliberately select LCMs because they facilitate the ability to fire many rounds without having to stop to reload. The second reason is that the ability of shooters to kill many victims—especially the 6 victims required to be included in our data set—may be reduced if LCMs are not available. In other words, the first explanation is that shooters perceive LCMs to be more effective at killing many people; the second explanation is that LCMs are indeed more effective at killing many people.

High-fatality mass shootings are not common, even in the United States. Between 1990 and 2017, there has been an average of 2.5 incidents per year, with an average of 25 people killed annually in such attacks. However, the number of incidents and the number of people killed per incident have been increasing since the end of the federal assault weapons ban.

In our study, we found that bans on LCMs were associated with both lower incidence of high-fatality mass shootings and lower fatality tolls per incident. The difference in incidence and overall number of fatalities between states, with and without bans, was even greater for LCM-involved high-fatality mass shootings.

The multivariate results are largely consistent with these bivariate associations. When we controlled for 10 independent variables often associated with overall crime rates, as well as state and year effects, states with LCM bans had lower rates of high-fatality mass shootings and fewer high-fatality mass shooting deaths. When we investigated federal and state bans separately in the multiple

TABLE 4—Multivariate Results of the Relationship Between Large Caliber Magazine Bans and High-Fatality Mass Shootings (≥6 Victims Shot to Death), 1990–2017 Separate Federal and State Large Caliber Magazine Bans: United States

	LCM-Involved High-Fatality Mass Shootings, b (95% CI)		All High-Fatality Mass Shootings, b (95% CI)	
	Incidents[a]	No. Deaths[b]	Incidents[a]	No. Deaths[b]
Federal LCM ban	−1.434 (−2.622, −0.245)	−3.571 (−7.103, −0.038)	−0.895 (−1.806, 0.016)	−2.570 (−4.902, −0.238)
State LCM bans	−2.603 (−4.895, −0.311)	−8.048 (−15.172, −0.925)	−1.277 (−2.977, 0.422)	−3.082 (−7.227, 1.064)
Population density	−0.012 (−0.055, 0.030)	−0.001 (−0.085, 0.083)	0.001 (−0.003, 0.006)	0.009 (−0.007, 0.024)
% aged 19–24 y	−0.311 (−1.499, 0.878)	−2.589 (−6.057, 0.879)	0.342 (−0.551, 1.236)	−0.531 (−2.759, 1.698)
% aged 25–34 y	−0.812 (−1.532, −0.093)	−2.660 (−4.848, −0.471)	−0.323 (−0.864, 0.217)	−0.848 (−2.236, 0.539)
% Black	−0.229 (−1.101, 0.643)	−0.770 (−3.232, 1.693)	−0.150 (−0.698, 0.398)	−0.154 (−1.321, 1.013)
% with a bachelor's degree or higher	−0.031 (−0.447, 0.509)	−0.479 (−1.577, 0.618)	0.156 (−0.199, 0.511)	0.269 (−0.567, 1.106)
Percentage of households with a firearm (proxy)	−0.055 (−0.210, 0.101)	−0.227 (−0.651, 0.196)	−0.019 (−0.133, 0.094)	−0.107 (−0.399, 0.186)
Median household income	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)
Unemployment rate	−0.061 (−0.284, 0.162)	−0.420 (−1.041, 0.201)	0.046 (−0.132, 0.224)	−0.157 (−0.619, 0.305)
Imprisonment rate (per 100 000 population)	−0.006 (−0.013, 0.000)	−0.012 (−0.026, 0.002)	−0.002 (−0.007, 0.003)	−0.003 (−0.014, 0.007)
Total population	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)	0.000 (0.000, 0.000)
Pseudo R^2	0.30	0.15	0.26	0.11

Note. CI = confidence interval; LCM = large-capacity magazine. There were a total of 1428 observations in state-years (51 jurisdictions—all 50 states plus Washington, DC—over a 28-year period). Mean variance inflation factor = 3.45.

[a]Logit regression.

[b]Negative binomial regression.

regressions, both were significantly associated with the incidence of LCM-involved high-fatality mass shootings as well as the number of victims in LCM-involved attacks. The relationship between these bans, considered separately, and all high-fatality mass shooting incidence and deaths is often not statistically significant, although this may be attributable to lack of statistical power (number of observations) to find a statistically significant effect.

Our analysis provides answers to 4 important questions:

1. How often are LCMs used in high-fatality mass shootings? At minimum, 64% of high-fatality mass shootings perpetrated between 1990 and 2017 involved LCMs.
2. Are more people killed when LCMs are used? Yes, and the difference in our data set is substantial and statistically significant (11.8 vs 7.3). We should add that our results likely underestimate the difference because we have a truncated sample (we only examined incidents with at least 6 victim fatalities), compounded by the fact that the number of homicide incidents fell as the number of victims increased.
3. Do states with LCM bans experience high-fatality mass shootings involving LCMs at a lower rate and a lower fatality count than those states with no such bans in effect? Yes. In fact, the effect is more pronounced for high-fatality mass shootings involving LCMs than for those not involving LCMs.
4. Do states with LCM bans experience high-fatality mass shootings (regardless of whether they involve LCMs) at a lower rate and a lower fatality count than states with no such bans in effect? Yes.

Limitations

Our study had various limitations. First, although we carefully searched for every high-fatality mass shooting, it is possible that we might have missed some. Nevertheless, we suspect that this is unlikely, because it would mean that others who compiled lists have also missed the same ones, for we checked our list against multiple sources.

Second, our definition of a high-fatality mass shooting is a shooting that results in 6 or more fatal victims. A different threshold criterion (e.g., 6 or more people shot; 5 or more victims killed), might lead to somewhat different results. We expect that as the number of victims in a shooting increases, the likelihood that the perpetrator used an LCM also increases. Indeed, of the 13 high-fatality mass shootings with 10 or more fatalities in our data set, 12 (92%) involved an LCM.

Third, although many high-fatality mass shootings tend to be highly publicized, in 13% of the incidents we reviewed, we could not determine whether an LCM was used. As a sensitivity analysis, we assessed the assumptions that all of the unknown cases first did, and then did not, involve LCMs. Neither assumption appreciably changed our main results (not shown).

Fourth, as a general rule, clustering standard errors is most appropriate when there is a large number of treated units. Although during the decade of the federal assault weapons bans all 50 states plus the District of Columbia regulated LCMs, during the remaining time periods under examination, only 8 jurisdictions regulated LCMs. As a result, there is the possibility that the standard errors were underestimated in our analyses.[34]

Fifth, there were only 69 events that met our criterion for a "high-fatality mass shooting." Although 69 is a horrific number of incidents, for statistical purposes, it is a relatively small number and limits the power to detect significant associations. For example, we did not have the statistical power (and thus did not even try) to determine whether

different aspects of the various LCM laws might have differential effects on the incidence of high-fatality mass shootings. Moreover, because of suboptimal statistical power, there is also the possibility that the magnitude of the effects detected was overestimated.[35]

Public Health Implications

LCMs increase the ability to fire large numbers of bullets without having to pause to reload. Any measure that can force a pause in an active shooting—creating opportunities for those in the line of fire to flee, take cover, or physically confront a gunman—offers a possibility of reducing the number of victims in such an attack. To put it in different terms, if the only firearms available were 18th-century muskets, it is doubtful that mass shootings would be the social problem they are today.

The impact of individual state firearm laws is reduced by the fact that guns often move across state lines—occasionally purchased in locales with more permissive laws and taken to states with more restrictive laws. This is partly why efforts aimed at reducing the frequency and lethality of mass shootings must necessarily be multifaceted and multidisciplinary. Legal restrictions on firearms are merely a part of this broader, public health approach. That being said, the theory behind reducing the availability of LCMs to reduce the number of victims in mass shootings makes sense, and our empirical results, consistent with much of the limited literature on mass shootings, suggest that LCM bans have been effective in saving lives. AJPH

CONTRIBUTORS

L. Klarevas and D. Hemenway designed the study, collected the data, and contributed equally to all parts of the study. A. Conner ran the statistical analyses and helped construct the tables that report the results of the multivariate analyses. All authors approved the final article as submitted.

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CONFLICTS OF INTEREST

L. Klarevas has, in the past 2 years, served as an expert to the states of Colorado and California in civil litigation that involved the constitutionality of state restrictions on large-capacity magazines. The authors have no additional conflicts of interest to report.

HUMAN PARTICIPANT PROTECTION

No protocol approval was needed because no human participants were involved in this study.

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